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THERMAL PERFORMANCE AND DELIVERY CAPABILITY OF PLASTIC CONSTRUCTION ELECTRIC WATER HEATER

E.A. Thompson

Test results are presented for a new design electric water heater. When tested in accordance to selected clauses of CSA Performance Standard C191-M1983 the "plastic" water heater met the standard requirements except for clause 5.5 - Heater Element Input and 5.8 - Thermostats. The new electric water heater design is compact, rigid and presents a modern looking appearance. Measured standby losses are 73.5 W indicating a potential energy saving of approximately 230 kWh/yr vs a standard electric water heater.

INTRODUCTION

Standard electric water heaters have the storage tank made of steel with the inner surface covered by a glass lining. The tank is thermally insulated with either fibreglass or polyurethane and the whole assembly is protected by an exterior jacket (outer case) made of sheet metal and painted.

In the "plastic" electric water heater, the storage tank is made of spun fibreglass material with interior lining of polybutylene. The fibreglass tank is surrounded with 50 mm thick polyurethane insulation and a plastic outer jacket. Several sizes are available including 114, 151 and 197 L (30, 40 and 52 US gallons).

The shape of the storage tank is somewhat different than that of a conventional electric water heater; the bottom end is concave (U) thus providing better drainage. The tested unit was equipped with two 3800 W resistance elements, (5500 W elements are also available) and in addition to the high limit switch standard in any electric water heater they have integral fusible

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links for over temperature protection. These links are of the non-resetting type and require the replacement of the element should they open the electrical circuit.

Thermostat arrangement is innovative and water temperature is sensed indirectly along a copper flange extending from the element mounting. Significant construction differences between the plastic constructed water heater and a standard electric water heater are illustrated in Figure A1.

TEST METHODS AND INSTRUMENTATION

The following tests, according to CSA Standard C191 Series - M1983, were performed to establish the thermal performance and delivery capability of the new water heater design: Delivery (Clause 5.11/3.8) Energy Efficiency - Standby Loss (5.6/3.9), Tank Capacity (5.4/3.1.5), Diffusion (5.7/3.1.6), Upper Zone (5.10/3.3.3), Thermostat Calibration and Controlled Temperature Differential (5.8.1/3.4.2 and 5.8.2/3.4.3) and Heater Element Input (5.5/3.3.5). To determine the recovery capability of the water heater an additional "heat-up" test, not required by the CSA standard, was also performed.

The delivery tests were conducted at 62.4°C (144°F) thermostat setting on two different delivery schedules with the same demand pattern as recommended by C191. The total daily amount of water drawn was 100 and 120%, (454 and 545 L) respectively, from the standardized total withdrawal (Table A1).

A programmed controller was used to implement the schedule and to keep performance records. Other quantities were recorded by a kWh meter, a water flow meter and two strip-chart recorders for the temperature probes (Figure A2). The thermostat calibration and controlled temperature differential tests were performed at thermostat settings shown in degrees Fahrenheit and converted to equivalent Celsius degree values. This was necessary because both upper and lower thermostats were originally marked in degrees Fahrenheit.

TEST RESULTS AND DISCUSSION

Thermal performance and delivery capability were found satisfactory. Results are summarized in Tables A2 to A11. Curves showing the recovery capability test results as well as the 454 and 545 L water draw schedules and average water temperature of each draw are illustrated in Figures A3 and A4.

Calibration tests indicated that both the upper and lower thermostats are not accurate enough. Thermostat settings of 60/76.7°C resulted in water temperatures of 68.7/91.5°C and 65.0/80.0°C for the upper and lower thermostat respectively. Also the heater element input was lower than both the rated wattage and the wattage tolerance (3510 and 3540 vs 3800 W).

The 120% delivery schedule is not part of the CSA requirement but it is an indicator of the water heating capacity under a high demand situation. Although the water temperature on the 5th and 6th draw was 43.5 and 46.4°C respectively and both were below the required lower limit of 50.4°C the delivery capability of the heater under these conditions was considered satisfactory.

The installation instructions recommend using flexible water plumbing couplings to the tank. Observations of the tank operation support this recommendation because the inner tank expands and contracts every time water is drawn from it, slightly moving the inlet and outlet pipes.

CONCLUSIONS

1. The "plastic" electric water heater satisfied most of the requirements of the selected clauses of CSA Standard C191-M1983 except for the following:

   Clause 5.5: Heater Element Input: lower than allowed. (3510 and 3540 vs 3800 W)

   Clause 5.8: Thermostats: both the upper and lower thermostats not accurate enough.

2. The recovery and delivery capability of the water heater was satisfactory.

3. Measured standby losses were 73.5 W indicating a potential maximum energy saving of approximately 230 kWh/yr versus a standard electric water heater.

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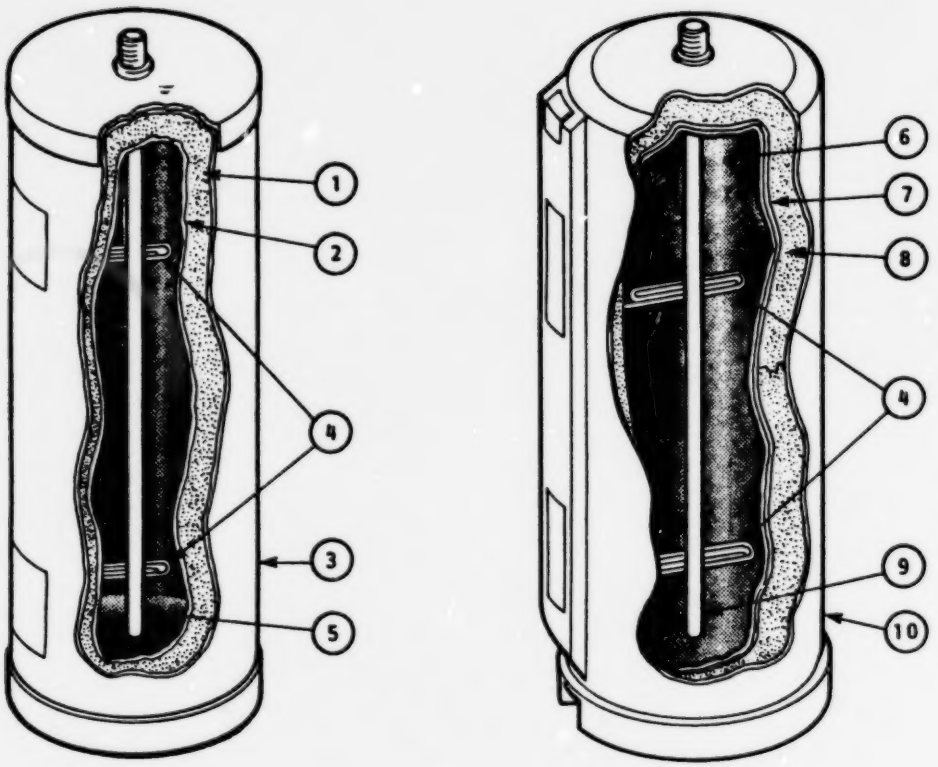
APPENDIX

DETAILED RESULTS



(a)
Conventional

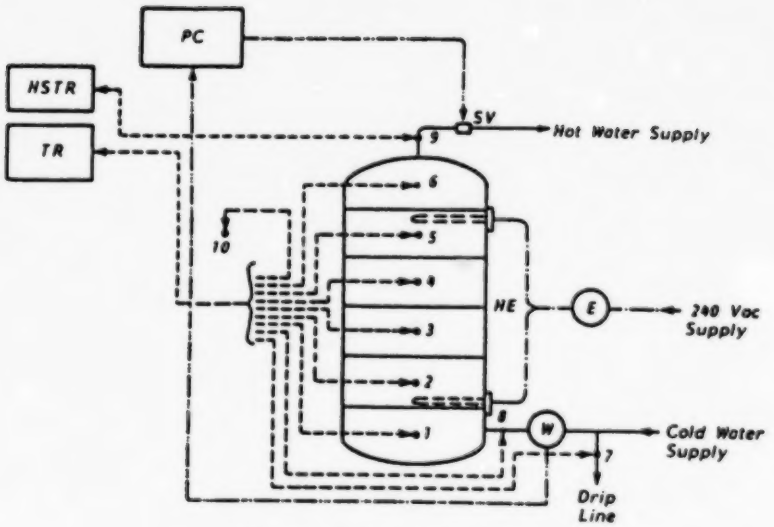
(b)
New "Plastic"

1. *Polyurethane or Fiberglas Insulation*
2. *Glass Lined Steel Tank*
3. *Steel Outer Case*
4. *Heating Elements*
5. *Magnesium Rod*
6. *Polybutylene Inner Tank*
7. *Fiberglas Outer Tank*
8. *Polyurethane Insulation*
9. *Dip Tube Cold Water Inlet*
10. *Polyethylene Outer Case*

EWU	Height	Nominal Diameter	Nominal Capacity	Weight
	mm	mm	litres	kg
a	*1260*	*620*	*175*	*66*
b	*1580*	*575**	*197*	*47*

** The front panel protrudes approximately 70mm beyond above nominal diameter.*

FIGURE A1
ELECTRIC WATER HEATERS



TR - Temperature Recorder
HSTR - High Speed Temp Recorder
PC - Programmed Controller
SV - Solenoid Valve
HE - Heating Elements
E - kWh Meter
W - Water Flow Meter
1-9 - Water Temperature Probes
10 - Ambient Temperature Probe

FIGURE A2
EXPERIMENTAL INSTALLATION - SCHEMATIC DIAGRAM

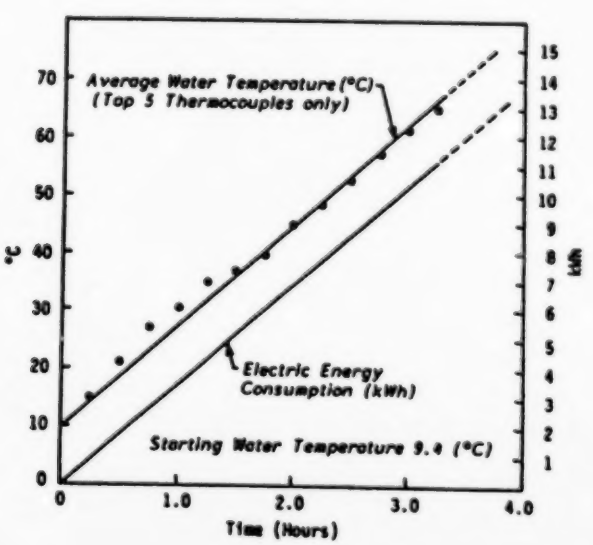


FIGURE A3
RECOVERY CAPABILITY TEST RESULTS

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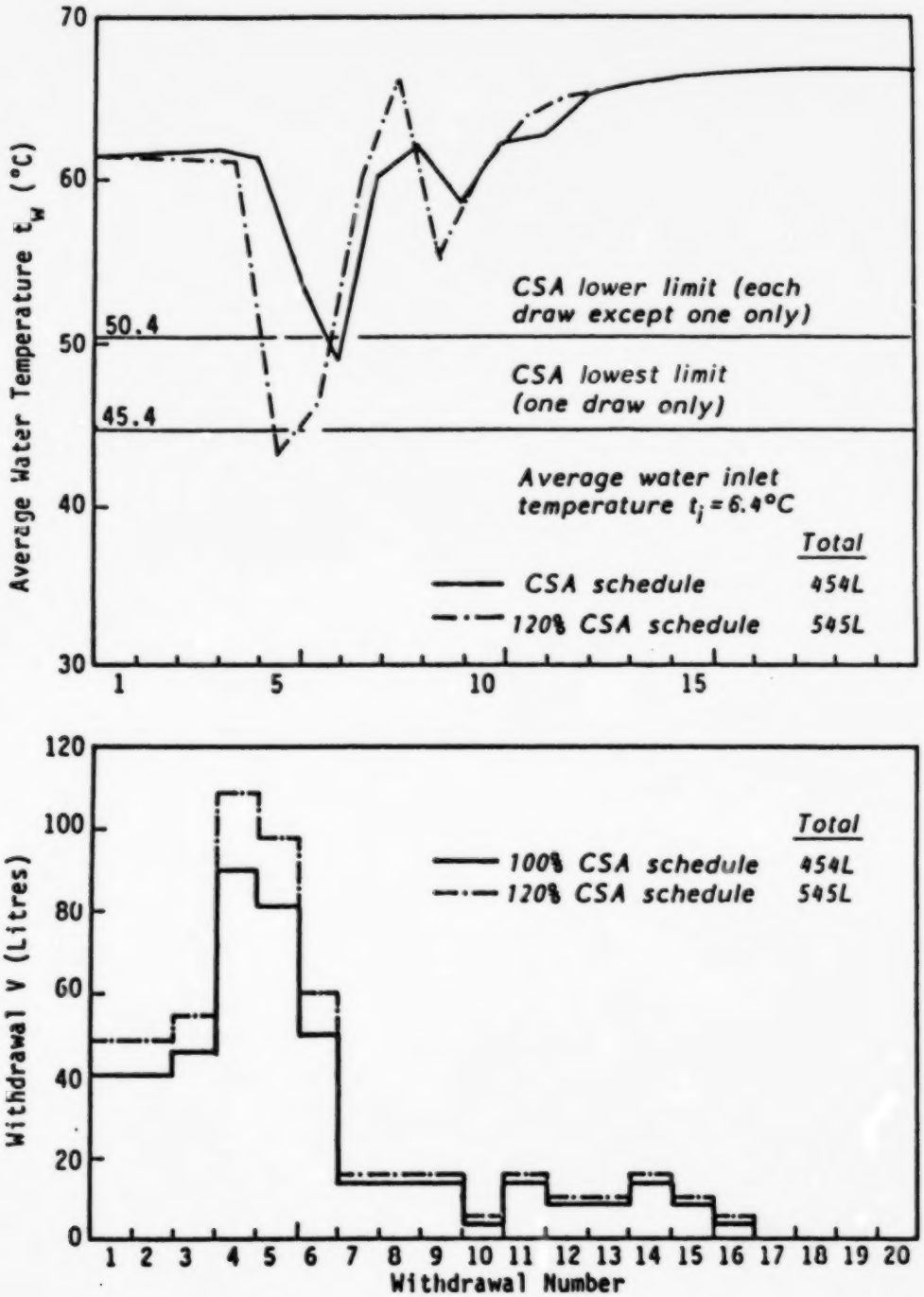

FIGURE A4

175L - DELIVERY TEST RESULTS

TABLE A1

ELECTRIC WATER HEATER 175L

DELIVERY SCHEDULES

WITHDRAWAL NUMBER	ELAPSED TIME HOURS	WITHDRAWAL LITRES	
		1	2
1	0	40.0	49.0
2	1.0	40.0	49.0
3	2.0	46.0	55.0
4	3.0	90.0	109.0
5	3.5	81.0	98.0
6	4.0	50.0	60.0
7	5.0	14.0	16.0
8	6.0	14.0	16.0
9	7.0	14.0	16.0
10	8.0	5.0	6.0
11	9.0	14.0	16.0
12	10.0	9.0	11.0
13	11.0	9.0	11.0
14	12.0	14.0	16.0
15	13.0	9.0	11.0
16	14.0	5.0	6.0
	Total	454.0	545.0

1 - CSA schedule
2 - 120% CSA schedule

TABLE A2

RECOVERY CAPABILITY TEST RESULTS

TIME	MIN.	0	15	30	45	60	75	90	105	120	135	150	165	180
AVG. WATER * TEMPERATURE	°C	9.4	14.9	21.04	27.04	30.18	34.82	36.88	39.66	44.92	48.5	52.7	57.1	61.2

* Five Top Thermocouples only.

TABLE A3

DELIVERY TEST RESULTS (CLAUSE 5.11)

THERMOSTAT SETTING	TOTAL WITHDRAWAL	AVERAGE WATER TEMPERATURE IN WITHDRAWAL NO	AVERAGE WATER SUPPLY TEMPERATURE	CSA REQUIREMENT
t_s (°C/F)	V (L/ GAL)	t_w (°C)	t_i (°C)	t_w (°C)
62.8 144	454 100	1 61.6 2 61.7 3 61.9 4 61.4 5 54.0 6 48.7	6.4	for: $t_s = t_i + 56.0$ a. one withdrawal only: $t_w \geq t_i + 39.0$ b. all other withdrawals: $t_w \geq t_i + 44.0$
	545 120	1 61.7 2 61.5 3 61.4 4 60.5 5 43.5 6 46.4	6.4	

TABLE A4

DELIVERY TEST RESULTS (COMPLETE CYCLE)

WITHDRAWAL NO	AVERAGE WATER TEMP DELIVERY SCHEDULE(°C)	
	454 LITRES	545 LITRES
0	61.6	61.7
1	61.6	61.7
2	61.7	61.5
3	61.9	61.4
4	61.4	60.5
5	54.0	43.5
6	48.7	46.4
7	60.4	60.2
8	62.2	66.3
9	58.8	55.7
10	62.5	61.0
11	64.4	63.8
12	65.2	65.2
13	66.0	66.0
14	66.4	66.4
15	66.8	66.6
16	67.2	67.0

TABLE A5

STANDBY LOSS (CLAUSE 5.6)

TANK CAPACITY	STANDBY LOSS		ENERGY SAVING	
	MEASURED	REQUIRED		
LITRES GAL	WATTS		WATTS	%
175 40	73.5	100	26.5	26.5

TABLE A6

TANK CAPACITY (CLAUSE 5.4)

RATED CAPACITY Vr	ACTUAL CAPACITY V_a	
	MEASURED	REQUIRED*
LITRES		
175	184.9	$175 \leq V_a \leq 187$

* $V_r \leq V_a \leq 1.07\ V_r$

TABLE A7

DIFFUSION (CLAUSE 5.7)

TANK CAPACITY	AVERAGE WATER SUPPLY TEMPERATURE	MAXIMUM TEMPERATURE IN TOP OF TANK	PERCENTAGE OF V_a DELIVERED BEFORE THE WATER TEMPERATURE DROPS MORE THAN 17 °C	
LITRES	°C	°C	MEASURED	REQUIRED
175	6.4	62.2	91.7%	min 90%

TABLE A8

UPPER ZONE (CLAUSE 5.10)

TANK CAPACITY	AVERAGE WATER SUPPLY TEMPERATURE	MAXIMUM TEMPERATURE IN TOP OF TANK	THE AMOUNT OF HOT WATER V_u WITHDRAWN BEFORE ITS TEMPERATURE DROPS MORE THAN 17 °C	
LITRES	°C	°C	MEASURED	REQUIRED*
175	6.4	62.4	46.0	46.2 ± 4.4

* $V_u = 0.25\ V_a \pm 0.025\ V_r$

TABLE A9

THERMOSTAT CALIBRATION (CLAUSE 8.1)

TANK CAPACITY	THERMOSTAT	SETTING TEMPERATURE	TEMPERATURE IN TOP OF TANK	
			MEASURED	REQUIRED
LITRES		°C/ F	°C	
175	UPPER	76.7 / 170	91.5	-
		60.0 / 140	68.7	60.0 ± 3.0
		48.9 / 120	54.4	-
	LOWER	76.7 / 170	80.0	-
		60.0 / 140	65.0	60.0 ± 3.0
		48.9 / 120	53.1	-

TABLE A10

THERMOSTAT CONTROLLED TEMPERATURE DIFFERENTIAL (CLAUSE 8.2)

TANK CAPACITY LITRES	THERMOSTAT	SETTING TEMPERATURE °C /°F	TEMPERATURE AT THERMOSTAT LEVEL		TEMPERATURE DIFFERENTIAL	
			IN	OUT	MEASURED	REQUIRED
		°C /°F	°C		°C	
175	UPPER	76.7/170	83.7	91.4	7.7	-
		60.0/140	53.5	68.9	15.4	$8.0 < \Delta T < 17.0$
		48.9/120	39.9	54.4	14.5	-
	LOWER	76.7/170	76.9	80.0	3.1	-
		60.0/140	63.1	65.5	2.4	$3.0 < \Delta T < 8.0$
		48.9/120	48.3	53.1	4.8	-

TABLE A11

HEATER ELEMENT INPUT TEST (CLAUSE 5.5)

LOCATION IN TANK	RATED VOLTAGE	RATED WATTAGE	MEASURED WATTAGE	WATTAGE TOLERANCE
UPPER	240	3800	3510	3610 TO 3990
LOWER			3540	